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Developing a resilience index towards natural disasters in Indonesia

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ABSTRACT

Most areas in Indonesia are prone to natural disasters, such as earthquakes, tsunami and volcano eruptions. In order to minimize the disaster impacts and shorten the recovery period, the resilience of a disaster-prone area is required to be assessed. This paper aims to develop a framework to assess the resilience of disaster-prone areas in Indonesia towards natural disasters, by establishing an index. In the framework, resilience is defined as the ratio between preparedness and vulnerability. The dimensions for preparedness are social, economic, community capacity, institutional and infrastructure. Similar dimensions applied for the vulnerability with additional dimension of hazard, come up with an index that is scaled from 0 to 1. The framework is applied to assess the resilience of Cilacap regency (in Central Java province) and the city of Padang (in West Sumatra province). The results show that both areas are resilient towards natural disasters, although certain improvements still can be made to further increase the resilience of both areas.

1. Introduction

Indonesia is considered as one of the disaster-prone countries. The country is located at the intersection of three crucial earth faults: the Pacific fault, Indo-Australian fault, and Eurasian fault. As a result, the country has to face with frequent and powerful seismic activity, such as earthquake and volcano eruption, and other types of natural disasters, e.g. tsunami, typhoon, and drought. According to The Indonesian National Agency for Disaster Management (BNPB), there were 12,494 disasters in the period of 2002–2012 with 190,087 numbers of casualties [1]. Natural disasters have significant impacts to many aspects of life of the residents in the affected areas, and the recovery from such a tremendous event can take a considerable amount of time.

Considering the significant impact of natural disaster, it is important to determine the level of disaster risk in a country's area. A deep understanding of the matter will help government to develop a comprehensive framework or policy to minimize the negative impact of disasters. In addition, understanding risk level should also be followed up by the assessment of resilience level toward the disasters. As mentioned by Mayunga [2], disaster resilience is the capacity or ability of a community to anticipate, prepare for, respond to, and recover quickly from impacts of disaster. Furthermore, disaster resilience along with economic vitality, environmental quality, social and inter-generational equity, quality of life, and participatory process are the six principles of sustainability [3].

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The objective of the study is to develop a framework to assess the resilience level of an area towards natural disasters, and to implement the framework by assessing the resilience of two disaster prone areas in Indonesia, namely Cilacap region and Padang city. By understanding the resilience level towards natural disasters, recommendations regarding public policy in disaster management that can improve the resilience of the area towards natural disasters can be made, so that the disaster's impact on the community and business can be reduced, and the recovery period can be shortened. The remaining of the paper is structured as follows. Section 2 discusses studies that have been done to define the resilience toward disaster, and those that are relevant to the development of resilience index. Section 3 explains the development of the resilience index, while Section 4 discusses the implementation of the framework to assess the resilience of Cilacap regency (similar to municipal/district) and the city of Padang toward natural disaster. Section 5 presents conclusions and recommendations for local government in both areas.

2. Relevant studies

The United Nations International Strategy for Disaster Reduction (UNISDR) defined resilience as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” [4].

Several definitions of disaster resilience were stated by researchers from different point of views. For instance, Paton and Johnston [5] viewed the resilience from the community perspective. They suggested that community resilience towards disaster required safeguarding the physical integrity, ensuring the continuity of economic, business and administrative activities, and also ensuring that the community members have the resources, capacities and capabilities necessary to utilize the physical and economic resources to minimize disruptions. Norris et al. [6] however, stated that community resilience is a set of networked adaptive capacities, namely economic development, social capital, information and communication, and community competence.

Mayunga [2] suggested a capital-based approach to study resilience towards natural disaster. He proposed five forms of capital that could contribute in reducing vulnerability and increasing community resilience, namely social, economic, human, physical, and natural, while Rose [7] views resilience from the economics perspective. He stated that economic resilience related to the behavior of individuals, markets and the regional macro-economy involving their inherent and adaptive response to hazards.

Scholars proposed many dimensions to measure the resilience. Bruneau et al. [8] proposed four inter-related dimensions of the resilience, namely technical, organizational, social, and economic, while Simpson [9] stated that hazards, community assets, social capital, infrastructure/system quality, planning, social services, and population demographics are indicators of the resilience. In addition, Razafindrabe et al. [10] proposed that there were five dimensions of resilience towards climate disaster, namely physical, social, economic, institutional, and natural (hazard frequency and hazard density). Meanwhile, Cutter et al. [11] proposed indicators of community resilience which included several dimensions, such as ecological, social, economic, institutional, infrastructure and community capacity, while Cutter et al. [12] excluded ecological dimension, and Ainuddin and Routray [13] used only four dimensions of resilience stated by Cutter [11], namely social, economic, institutional, and physical (shelter). In addition, Norris et al. [6] suggested that economic development, social capital and community competence are important variables for community resilience.

Previous studies more or less suggested the same dimensions of resilience, namely social, community capacity, economic, institutional, infrastructure/physical, and natural/ecological. However, different meanings of economic and natural/ecological resilience are used by researchers. For instance, Rose [7] viewed economic resilience as inherent or adaptive response of individuals, market, and market economy to hazard, while Cutter et al. [12] viewed economic resilience as the economic vitality of the community. Similarly, Razafindrabe et al. [10] suggested that natural resilience was related to hazard frequency and hazard intensity, while Cutter et al. [11] suggested that ecological resilience was influenced by factors such as biodiversity and spatiality.

Several studies also developed methods to determine indexes related to disaster risk management, such as resilience and vulnerability indexes. For instance, Cardona [14] developed an indicator system for disaster risk management, using four indicators which were Disaster Deficit Index (DDI), Local Disaster Index (LDI), Prevalent Vulnerability Index (PVI) and Risk Management Index (RMI). DDI measures a country risk from macroeconomic perspective and financial from catastrophic event. DDI is a ratio between maximum considered events (MCE) loss to economic resilience. LDI measures environment and social risk from disaster with smaller scale but occur frequently. PVI describes prone condition by measuring exposure in disaster-prone area, socio-economic fragility and lack of social resilience. RMI is a group of indicators that measures a country performance in risk management.

Simpson [9] proposed a model of resilience index of a community, namely the individual Disaster Resilience Index (DRi) which was a composite result of the presumed relationship between community preparedness measures (DPi) and the derivation of a community vulnerability score of the area. The measures of resilience were determined and weighted as functional measures of preparedness (FM), and vulnerability measures (VM). FM and VM were based on measuring spatial and non-spatial indicators across a range of community assets, including physical, economic, socio-cultural and ecological dimensions of capital.

Other method proposed by Rygel et al. [15] who introduced a method to construct social vulnerability index based on Pareto ranking. In essence, the indicators of vulnerability were developed and principal component analysis was performed on proxies of indicators. They applied Pareto ranking to the principle components in calculating overall social vulnerability. On the other hand, Mayunga [2] proposed a community disaster resilient index (CDRi) which was calculated as the average of weighted sum of the five capital indexes. Each capital index was calculated as the weighted sum of all its indicators. Chen et al. [16] employed Delphi method to determine the factors that influence urban and regional disaster carrying capacity (UR-DCC), and Analytical Hierarchy Process (AHP) was used to develop the evaluation model due to its ability to consider both qualitative and quantitative information and combining them by decomposing ill-structured problems into systematic hierarchies.

Cutter et al. [12] used composite indicators to assess the disaster resilience of counties in Southeastern of the United States. The term composite indicator refers to a manipulation of individual variables to produce an aggregate measure of disaster resilience. Based on literature study, they applied a place-based model, and constructed 30 indicators to compose resilience index of five subcomponents. Those indicators consisted of social resilience, economic resilience, institutional resilience, infrastructure resilience, and community capital. Furthermore, Sherrieb et al. [17] assessed the community resilience on the US coast using a web-based survey with school principals as informants. The survey questionnaire consisted of questions related to community competence, disaster management, social capital, economic development, and information and communication. Other framework used to assess the community resilience was conducted by Joerrin et al. [18]. They used climate-related disaster community resilience framework (CDCRF) to gauge the community resilience to climate related disasters in Chennai, India through a household survey. Orencio and Fujii [19] proposed a localized disaster resilient index to assess coastal community based on AHP. The criteria used were classified into environment and natural resource management, human health and wellbeing, sustainable livelihoods, social protection, financial instruments, physical protection, structural and technical measures, and planning regimes. Each criterion consisted of elements that were grouped into disaster-resilient community and risk-reduction enabling environment. The composite index for the disaster-resilient coastal community was measured using a weighted linear average approach of all indicators.

It can be seen that a variety of methods, such as survey, composite of indicators, AHP, and Delphi, have been used to develop the indexes. Even though different indexes to assess resilience towards disaster have been developed and relatively use the same criteria, different countries may require adjustments in sub-criteria and indicators of resilience. For this purpose, we develop a framework to assess the resilience of areas in Indonesia towards natural disaster.

3. Development of the resilience index

In this study, we use the definition of resilience from UNISDR [4], which in essential defines resilience as the ability to resist, absorb and accommodate and recover from the effect of hazard in timely and efficient manner. Therefore, the resilience index proposed here is based on Simpson [9] that stated community resilience as the ratio of community preparedness to its vulnerability. Preparedness refers to the capacity to handle disaster [9], while vulnerability is defined as the potential for loss [20].

In our model, the resilience of the area is determined by comparing the preparedness versus the vulnerability (exposure toward disaster). The goal for the community is to maximize the preparedness potential and minimize their vulnerability. [9] Higher preparedness will result in higher resilience, while higher vulnerability will result in lower resilience. The preparedness and vulnerability scores are determined using AHP from Saaty [21].

In order to determine the dimensions of preparedness and vulnerability, we conducted 17 in-depth interviews (IDIs) with representatives of several agencies that are usually involved in disaster management, which include: Agency for Disaster Management at the District Level, Indonesia Red Cross at the district level, Division of Social Welfare at district level, Division of Public Works at the district level, and Division of Health at the district level in four disaster-prone areas in Indonesia, namely Cilacap, Padang, Palu, and Yogyakarta. We also conducted 4 focus group discussions (FGDs) with representatives from the non-governmental organizations (NGOs) that are usually engaged in disaster management, and the community leaders in each area.

Based on the IDIs and FGDs results as well as the literature review, we conclude that resilience is a function of preparedness and vulnerability (see our previous study by Viverita et al. [22]). The dimensions of preparedness are namely social, community capacity, economic, institutional, infrastructure. Similar dimensions applied for the vulnerability with additional dimension of hazard (see Fig. 1). Social resilience is a function of demographic characteristics and access to resources [12], while community resilience is related to the attributes of the area that promote population wellness, quality of life, and emotional health [9], and economic resilience is related to the economic vitality of the community [12]. Furthermore, institutional resilience is related to the efforts of local government to raise the awareness and preparedness of the residents toward disaster [13]. According to Razafindarabe et al. [10] and Cutter et al. [11], infrastructure resilience is related to the physical aspects of the area, such as electricity, water supply, sanitation, and transportation network. Lastly, since hazard normally affects the resilience of the area, it is included in model. Hazard is a part the vulnerability that is related to the exposure to natural disasters represented by hazard frequency and hazard intensity [10].

The indicators for preparedness and vulnerability are selected from indicators proposed by previous studies, and also from the results of the abovementioned IDIs and FGDs. The dimensions and sub-dimensions of preparedness for each area

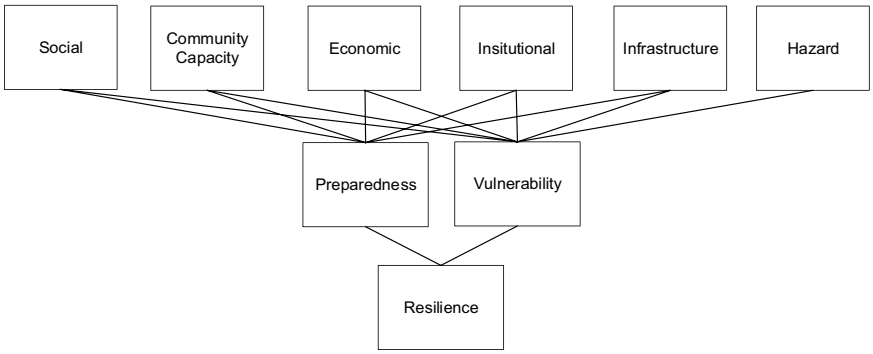

Fig. 1. The resilience framework.

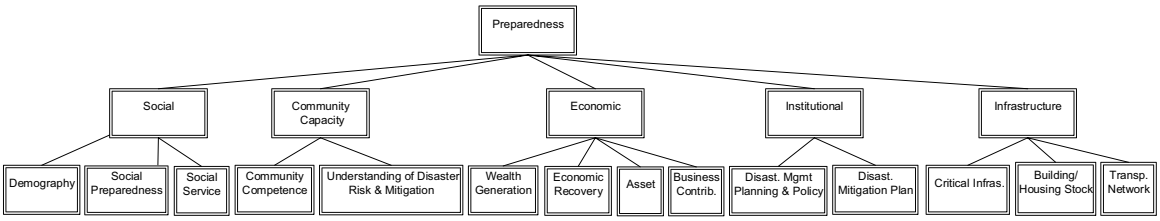

Fig. 2. Dimensions and sub-dimensions of preparedness.

are presented in Fig. 2 while the descriptions of sub-dimensions and indicators are presented in Table 1. The total number of indicators considered for preparedness is 49.

The dimensions and sub-dimensions of vulnerability are presented in Fig. 3, while the descriptions of sub-dimensions and indicators are presented in Table 2. The total number of indicators for vulnerability is 18.

As previously explained, resilience of the area is a function of its preparedness and vulnerability. We use composite indicator to determine the preparedness and vulnerability scores as in [2,8,12,19] The preparedness score (*PI*) is calculated as the sum of weighted score of all dimensions' scores (*PD*), whereas the dimension score is calculated as the sum of weighted of all sub-dimensions' scores (*PS*). Lastly, the sub-dimension score is calculated as the average score of its indicators.

$$PI = \sum_{i=1}^{i=NP} w_i PD_i \tag{1}$$

$$PD_i = \sum_{j=1}^{j=MP_i} u_{ji} PS_{ji} \tag{2}$$

$$PS_{ij} = \frac{\sum_{k=1}^{k=LP_j} PC_{ijk}}{LP_j} \tag{3}$$

where

PI = preparedness score of the area
PD_i = score of preparedness dimension i
PS_{ji} = score of sub-dimension j of preparedness dimension i
PC_{kji} = score of indicator k of sub-dimension j of preparedness dimension i
w_i = weight of preparedness dimension i
u_{ji} = weight of sub-dimension j of preparedness dimension i
NP = number of dimensions of preparedness
MP_i = number of sub-dimensions of preparedness dimension i
LP_j = number of indicators of preparedness sub-dimensions j

Table 1
Descriptions of indicators of preparedness.

Dimensions	Sub-dimensions	Descriptions	Indicators	Source	Source of data
Social	Demography	Demographic characteristics of the area	1. Percentage of population with productive age	[12,23]	Secondary data
			2. Percentage of population that are literate	[12,23]	Secondary data
			3. Percentage of population that graduated from high school	[12,6,23]	Secondary data
	Social preparedness	The preparedness of the residents toward a natural disaster	4. Percentage of population with vehicle	[12,24]	Secondary data
			5. Percentage of houses with fixed line telephone	[12,25]	Secondary data
			6. Percentage of population covered by community medical service (Jamkesmas)	[12,26]	Secondary data
			7. Household initiatives to provide voluntary support during a critical situation	IDIs and FGDs results	Questionnaire
	Social services	The activities of non-governmental organizations/institutions in disaster mitigation	8. Number of volunteers	[12,27]	Secondary data
			9. Number of registered NGOs	IDIs and FGDs results	Secondary data
			10. Number of companies involved in disaster mitigation/ response	IDIs and FGDs results	Secondary data
Community capacity	Community competence	The local wisdom and the level of participation of the community in developing their competence	11. The area has influential community leaders	IDIs and FGDs results	Questionnaire
			12. People in the community helps each other	IDIs and FGDs results	Questionnaire
			13. The level of activity of the Posyandu (post of integrated services for family) program	[17]	Questionnaire
			14. Frequency of meetings between community leaders and their people	[17]	Questionnaire
			15. The community is actively participating in NGOs' programs	[17]	Questionnaire
			16. The involvement in programs to develop community competence (religious study, women and family program, youth activities)	[17]	Questionnaire
	Understanding of disaster risk and mitigation	The level of understanding of the residents regarding the disaster risk in the area and its mitigation	17. The understanding of disaster-prone area through education programs provided by governments/NGOs	IDIs and FGD results and [11]	Questionnaire
			18. The understanding of the disaster-risk level of the area through education programs provided by governments/ NGOs	IDIs and FGDs results and [11]	Questionnaire
			19 The understanding of the efforts to cope with disaster in the area through education programs provided by governments/NGOs	IDIs and FGDs results and [11]	Questionnaire
			20. The understanding of the efforts to recover from disaster in the area through education programs provided by governments/NGOs	IDIs and FGDs results and [11]	Questionnaire
Economic	Wealth generation	Income of the residents	21. Municipal income per capita	[6,12]	Secondary data
	Economic recovery	The capability to recover economically from the disaster	22. The existence of saving fund in the family	[11]	Questionnaire
			23. Percentage of emergency fund	[11]	Questionnaire
			24. Number of family members with employment	[11]	Questionnaire
			25. Number of ways to earn income of the head of household	[11]	Questionnaire
	Asset	Asset owned by the residents	26. Total saving per capita	[11]	Secondary data
			27. Percentage of population that own houses	[6,11,12]	Secondary data
	Business contribution	Business contribution to the local economy	28. Gross regional domestic product (GRDP) per capita	[11]	Secondary data
			29. Percentage of municipal tax in municipal revenue	[6,12]	Secondary data
Institutional	Disaster management planning and policy	Disaster management planning and policy of the local government	30. The existence of disaster management agency at the municipal level (BPBD)	[12,28]	Secondary data
			31.	[12,29]	Secondary data

Table 1 (*continued*)

Dimensions	Sub-dimensions	Descriptions	Indicators	Source	Source of data
			Percentage of municipal's budget for disaster management (for BPBD in the area)		
			32. The existence of municipal's regulation for disaster response	[11,28]	Secondary data
			33. Is there any coordination with community leader, social organization & NGOs, and business community?	[11,28]	Secondary data
	Disaster mitigation plan	Mitigation plan of the local government, including the availability of disaster management infrastructure	34. The number of sirens for early warning systems	[11]	Secondary data
			35. Number of evacuation signs per square km	[12, [30]	Secondary data
			36. Shelter coverage (percentage of population covered by the assigned shelters in disaster prone area)	[12,24]	Secondary data
			37. Number of logistics warehouses	[11]	Secondary data
			38. Number of hospital beds per 1000 people	[12,31]	Secondary data
			39. Percentage of population exposed to disaster management education/ socialization	[12,27,32]	Secondary data
			40. Number of disaster management education/socialization activities per year	[12,27,32]	Secondary data
			41. Existence of disaster of information center	[11]	Secondary data
			42. Existence of disaster information system dissemination	[11]	Secondary data
Infra-structure	Critical infrastructure	The availability of electricity, clean water and sanitation in the area	43. Percentage of houses with electricity	IDIs and FGDs results and [11]	Secondary data
			44. Percentage of houses with access to clean water	IDIs and FGDs results and [11]	Secondary data
			45. Percentage of houses with sanitation and solid waste facilities	IDIs and FGDs results and [11]	Secondary data
	Building/housing stock	The housing condition and public facility density of the area	46. Percentage of houses with brick walls	[11]	Secondary data
			47. Number of public facilities per square km (school, religious facilities, sport stadium, government offices, community health centers, hospitals)	[12,24]	Secondary data
	Transportation network	The existing transportation network and transportation access to the area	48. The length of road per square km	[11]	Secondary data
			49. Number of transportation access to the area	[11]	Secondary data

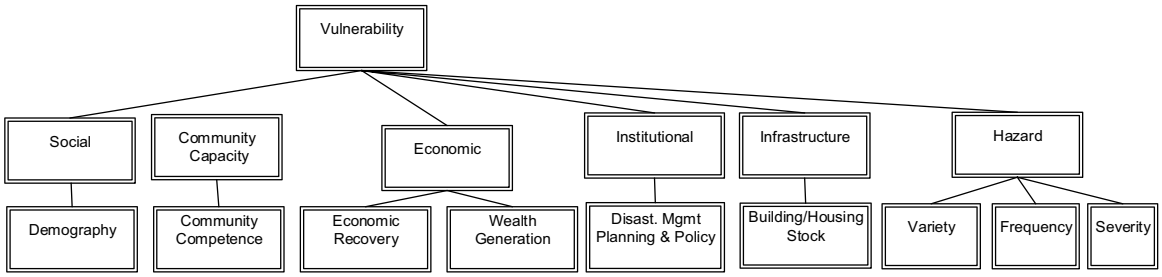

Fig. 3. Dimensions and sub-dimensions of vulnerability.

The vulnerability score (*VI*) is calculated the same way as preparedness score.

$$VI = \sum_{i=1}^{i=NV} y_i VD_i \tag{4}$$

$$VD_i = \sum_{j=1}^{j=MV_i} x_{ji} VS_{ji} \tag{5}$$

$$VS_{ij} = \frac{\sum_{k=1}^{k=LV_j} VC_{ijk}}{LV_j} \tag{6}$$

where

VI = vulnerability score of the area
VD_i = score of vulnerability dimension i
VS_{ji} = score of sub-dimension j of vulnerability dimension i
VC_{kji} = score of indicator k of sub-dimension j of vulnerability dimension i
y_i = weight of vulnerability dimension i
x_{ji} = weight of sub-dimension j of vulnerability dimension i
NV = number of dimensions of vulnerability
MV_i = number of sub-dimensions of vulnerability dimension i
LV_j = number of indicators of vulnerability sub-dimensions j

The resilience score (*RI*) is then calculated as the ratio of preparedness score to vulnerability score (see Fig. 3).

$$RI = \frac{PI}{VI} \tag{7}$$

If the value is lower than one, it indicates that the area is not resilient toward natural disaster as the capacity to overcome the disaster is lower than its vulnerability. If the value is equal to 1, it means that the area just have enough capacity to overcome its vulnerability. If the value is more than one, it implies that the area is resilient towards natural disaster as it has the capacity to overcome its vulnerability.

Pairwise-comparisons method with nine scale from the Analytical Hierarchy Process [20] is employed to determine the weights of all dimension and sub-dimensions of preparedness and resilience.

As can be seen in Tables 1 and 2, most of the indicators for preparedness and vulnerability are measured by using secondary data, which are published or supplied by the Indonesian Statistics Bureau (BPS), the National Agency for Disaster Management (BNPB), and the Regional Agency for Disaster Management (BPBD) in Cilacap and Padang. However 15 indicators for preparedness and 1 indicator for vulnerability that cannot be measured using secondary data are measured using a survey questionnaire. We applied purposive sampling method to capture information from local residents whereby the survey involved 400 individual respondents in each area. The survey was conducted in the period of April–May 2013.

The score values for all indicators are between zero and one. Several techniques are used to score the indicators. Scoring for indicators with secondary data as measures is performed using the following ways:

1. Indicators that ideally have the value of 100 percent (such as percentage of population that are literate) are scored as it is.
2. Indicators that have no scoring standards are scored using min–max rescaling scheme, as is in [12], using provinces' data in Indonesia.
3. Indicators that have no scoring standards and only have the average national data are normalized using the national data.

Table 2
Descriptions of indicators of vulnerability.

Dimensions	Sub-dimensions	Descriptions	Indicators	Source	Source of data
Social	Demography	Vulnerability related to demographic characteristics of the area	1. Population density	[11]	Secondary data
			2. Unemployment rate	[12,33]	Secondary data
			3. Percentage of population living in poverty	[11]	Secondary data
			4. Percentage of population residing in disaster-prone area	[11]	Secondary data
			5. Percentage of population with special needs	[12,26]	Secondary data
Community capacity	Community competence	Vulnerability related to community	6. Number of social conflicts in the 15 years	[11]	Secondary data
			7. Number of criminal events per population	[11]	Secondary data
Economic	Wealth generating	Vulnerability related to wealth generating	8. Average expense per capita	[11]	Secondary data
			9. Portion of expense for everyday needs	[11]	Questionnaire
	Economic recovery	Vulnerability related to economic recovery	10 Number of family members living in the same house	[11]	Secondary data
Institutional	Disaster management planning and policy	Vulnerability related to disaster management planning and policy	11. Number of villages in the regency/city	[6,12]	Secondary data
Infrastructure	Building/housing stock	Vulnerability related to building/housing	12. Percentage of land used as residential area	[11]	Secondary data
Hazard	Variety	Variety of natural disasters occurred in the area	13. Variety of natural disasters (in last 15 years)	IDIs and FGDs results	Secondary data
	Frequency	Frequency of natural disasters occurred in the area	14. Frequency of disaster (in last 15 years)	[10]	Secondary data
	Severity	The severity of impact caused by the largest-scale of disaster occurred in the area	15. Number of death casualty in the largest scale of disaster (in last 15 years, reported)	[10]	Secondary data
			16. Number of injured casualty in the largest scale of disaster (in last 15 years, reported)	[10]	Secondary data
			17. Asset loss in the largest scale of disaster (in last 15 years, reported)	[10]	Secondary data
			18. Number of damaged building in the largest scale of disaster (in last 15 years, reported)	[10]	Secondary data

Table 3
Weights of preparedness dimensions and sub-dimensions.

Dimensions	Sub-dimensions	Weights
Social		0.137
Community capacity		0.291
Economics		0.161
Institutional		0.269
Infrastructure		0.143
Social	Demography	0.299
	Social preparedness	0.421
	Social services	0.280
Community capacity	Community competence	0.549
	Understanding dist. risk and mitigation	0.451
Economics	Wealth generating	0.208
	Economic recovery	0.455
	Asset	0.202
	Business contribution	0.135
Institutional	Disaster mgmt. plan and policy	0.452
	Disaster mitigation plan	0.548
Infrastructure	Critical infrastructure	0.534
	Building stock and age	0.197
	Trans. network	0.222

Table 4
Weights of vulnerability dimensions and sub-dimensions.

Dimensions	Sub-dimensions	Weights
Hazard		0.206
Social		0.216
Community capacity		0.138
Economics		0.098
Institutional		0.156
Infrastructure		0.177
Hazard	Variety	0.204
	Frequency	0.322
	Severity	0.475
Economics	Wealth generating	0.453
	Economic recovery	0.547

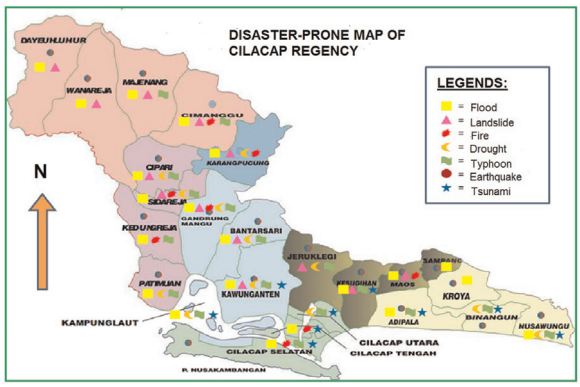

Fig. 4. Disaster prone map of Cilacap regency [36].

4. Implementing the framework

4.1. The weights of dimensions and sub-dimensions of preparedness and vulnerability

In order to determine the weights of dimensions and sub-dimensions of preparedness and vulnerability we used pairwise comparison based on the result of IDIs with eights experts and practitioners in disaster management in the period of March–April 2013 (see Tables 3 and 4). These experts are representatives from government institutions, the Indonesian Red

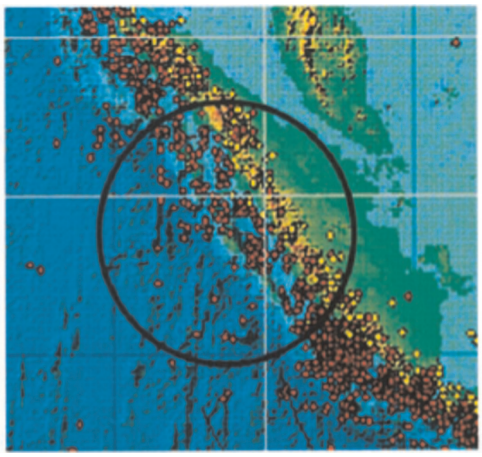

Fig. 5. Red zones of earthquake and tsunami in city of Padang [37].

Table 5
Preparedness dimensions and sub-dimensions score.

Dimension	Sub-dimension	Cilacap	Padang
Social	Demography	0.6473	0.7611
	Social preparedness	0.5850	0.7785
	Social services	0.9333	1.0000
	Social dimension score	**0.7010**	**0.8351**
Economic	Wealth generating	0.0944	0.1567
	Economic recovery	0.5903	0.8163
	Asset	0.7683	0.5825
	Business contribution	0.2149	0.3750
	Economic dimension score	**0.4725**	**0.5724**
Community capacity	Community competence	0.7395	0.7116
	Understanding dist. risk and mitigation	0.5708	0.7407
	Community dimension score	**0.6633**	**0.7246**
Institutional	Disaster mgmt. plan and policy	1.0000	1.0000
	Disaster mitigation plan	0.6325	0.5128
	Institutional dimension score	**0.7987**	**0.7331**
Infrastructure	Critical infrastructure	0.9753	0.8749
	Building stock and age	0.8280	0.9136
	Trans. network	0.7782	1.0000
	Infrastructure imension score	**0.8563**	**0.8689**
Preparedness score		**0.7013**	**0.7378**

Cross and NGOs in Jakarta, Padang, and Cilacap. Experts in Jakarta (the capital city of Indonesia) are also interviewed as they are usually involved in the disaster management in the other provinces of Indonesia.

As can be seen in Tables 3 and 4, community is perceived by informants as the most important factor that determines preparedness of the area, while social and hazard are the two most important factors that cause vulnerability of the area.

4.2. Assessing the resilience of Cilacap regency and Padang city

Cilacap is one of the regencies in Central Java which has a population around 1.75 million people in 2011, with the density of 821 people per square kilometers [34]. The gross regional domestic product (GRDP) of Cilacap in 2011 was around USD 2.07 billion, with agriculture sector and trade sector as the highest and second highest contributors, respectively [34].

Padang city, on the other hand, is the capital city of West Sumatra province, whose population is around 847 thousand people in 2011 and density of 1199 people per square kilometers [35]. The GRDP of Padang in 2011 was around USD 1 billion, with transport and communication sector, and trade, hotel and restaurant sector as the highest and second highest contributors, respectively [35].

Table 6
Vulnerability dimensions and sub-dimensions score of Cilacap.

Dimension	Sub-dimension	Cilacap	Padang
Social	Demography	0.5482	0.3226
	Social dimension score	**0.5482**	**0.3226**
Community capacity	Community competence	0.0000	0.0848
	Community dimension score	**0.0000**	**0.0848**
Economic	Wealth generating	0.6876	0.8964
	Economic recovery	0.2337	0.5258
	Economic dimension score	**0.4393**	**0.6937**
Institutional	Disaster management planning and policy	0.5652	0.1533
	Institutional dimension score	**0.5652**	**0.1533**
Infrastructure	Residential housing stock	0.0500	0.2025
	Infrastructure dimension score	**0.0500**	**0.2025**
Hazard	Variety	0.7143	0.8571
	Frequency	1.0000	1.0000
	Severity	0.5885	0.9415
	Hazard dimension score	**0.7473**	**0.9441**
Vulnerability score		**0.4124**	**0.4036**

Cilacap regency is prone to several types of disaster, such as earthquake, tsunami, landslide, and typhoon; however Padang city is prone especially to earthquake and tsunami (See Figs. 4 and 5).

4.2.1. The preparedness score

The dimension and sub-dimension scores for preparedness in Cilacap and Padang are presented in Table 5. As can be seen, the preparedness score of Padang is higher than that of Cilacap, due to the higher scores in four out of five dimensions.

The social preparedness sub-dimension score of Cilacap, in particular, is below 0.60, due to low percentage of household with fixed line (4.04%), and the score of household initiatives to provide voluntary support during critical situation which is below 0.70. This situation can be improved by socializing and educating the local community so that more people are encouraged to offer their help during emergency situation. The social services sub-dimension, on the other hand, has a good score (0.9333) indicating that there exists sufficient volunteers for disaster response, and NGOs and business entities have already been involved in disaster mitigation. Concerning social preparedness sub-dimension score of Padang, it still below 0.80. Similarly to Cilacap, socializing and educating the local community may improve the situation. In terms of social services sub-dimension, however, it has a maximum score (1.000) indicating that there are sufficient volunteers for disaster response, and NGOs and business entities are actively involved in disaster mitigation.

Concerning the economics preparedness, both areas have relatively low scores. For Cilacap, economic recovery which has the highest weight (0.455) has the score value around 0.59, indicating the difficulty that may be faced by the households in Cilacap to fully recover economically in the aftermath of the disaster. The other two sub-dimensions that have the relatively same weights are wealth generating and asset (0.208 and 0.202, respectively). Wealth generating sub-dimension, in particular, has the lowest score (0.0944) as a result of lower municipality income per capita compared to other areas in Indonesia. In terms of asset, the score is 0.7683, implying the current economic condition of the households in Cilacap which have relatively sufficient asset that can be used for emergency purpose. However, the business contribution has a low score of 0.2149, indicating that low contribution of business to the regency's economy. For Padang, economic recovery has the highest score around 0.82, indicating the households in Padang are relatively able to fully recover economically in the aftermath of the disaster. Wealth generating sub-dimension, in particular, has the lowest score (0.1567) as a result of lower municipality income per capita compared to other area in Indonesia. In terms of asset, the score is relatively better (0.5825), implying the current economic condition of the households in Padang which have relatively sufficient asset that can be used for emergency purpose due to high total saving per capita.

Regarding the community capacity preparedness, the scores in Cilacap and Padang are 0.6633 and 0.7246, respectively. This dimension includes two sub-dimensions with relatively similar weights. The community competence score of Cilacap is slightly higher than Padang, indicating the relatively higher level of activity of the community in developing their competence in the area. However, the score for understanding disaster risk and mitigation is significantly lower than that of Padang, implying the relatively low level of understanding of the sample residents of the disaster risk that the area currently faces, and the mitigation efforts by the government and other parties.

Concerning the institutional preparedness, the scores in two areas are relatively high at 0.7987 and 0.7331, respectively. The score for disaster management plan and policy for both areas is 1.00, indicating that the local government already has adequate policy and regulation put in place for disaster management in the area. However, the scores for disaster mitigation

plan are still 0.6325 and 0.5128, implying the need to improve the mitigation plan for both areas to minimize the disaster impacts and the recovery time.

In terms of infrastructure preparedness, the scores of Cilacap and Padang are relatively high at 0.8563 and 0.8689, respectively. All sub-dimensions have relatively good scores, indicating that most of the residents are covered with electricity, and their households have sanitation and access to clean water. Furthermore, around 75% of houses in Cilacap and 83% houses in Padang are made with bricks (implying durable residential places), and there are enough public facilities that can be used as emergency shelters. Lastly, Cilacap and Padang have sufficient transportation access (by road, by train, by air, by sea) that makes it easier to evacuate the residents and transporting relief supplies in the case of an emergency situation.

4.2.2. The vulnerability score

The dimension and sub-dimension scores of vulnerability in Cilacap and Padang are presented in Table 6. The vulnerability scores of both areas are around 0.4. For Cilacap, this is due to the high weights of social and hazard dimensions (0.216 and 0.206, respectively), and their relatively high vulnerability scores (0.5482 and 0.7473, respectively). In terms of hazard, Cilacap has experienced 5 out of 7 types of natural disasters, and the number of disaster events in this area for the last 15 years is relatively high, but more importantly, it experienced an earthquake in 2006 that caused significant human loss and asset loss. Therefore, the area is very prone to natural disasters. Regarding the social vulnerability, the demographic characteristics of Cilacap (such as high percentage of people living poverty and high percentage people living in disaster prone area) make it more vulnerable to disasters.

For Padang, the vulnerability score is due to high scores of hazard and economic dimensions (0.940 and 0.6937, respectively). In terms of hazard, Padang has experienced 6 out of 7 types of natural disasters, and high number of disaster events in the last 15 years. It experienced an earthquake in 2009 that caused significant human and losses, which caused the area to be very prone to natural disasters.

Concerning the community vulnerability, the score of Cilacap is 0.00, while the score of Padang is 0.0848, indicating there are very few social conflicts in Padang in the last 15 years, and compared to other areas in Indonesia. This situation should be maintained as social dimension is the factor that mostly determines the vulnerability of the area.

Regarding the economics vulnerability, the scores of Cilacap and Padang are 0.4393 and 0.6937, respectively. This is mainly caused by the high vulnerability score in wealth generating due to higher expense per capita and higher portion of expense for everyday needs compared to other areas in Indonesia.

In terms of institutional vulnerability, Cilacap has significantly higher score than Padang, which is caused by the large number of villages that must be managed by the local government. It implies the need to give more effort in coordinating with the head of villages and the community leaders in disaster mitigation and response activities.

Lastly, the score for infrastructure vulnerability of Cilacap is lower than that of Padang, which is caused by the low percentage of area that is used as residential area. It implies the relatively easier task to evacuate the residents in the event of a disaster.

4.2.3. The resilience score of Cilacap and Padang

The resilience score of Cilacap regency toward natural disaster is 1.7006, which is slightly lower than the score of Padang (1.8280), indicating that both areas have the capacity to overcome the vulnerability to disaster. However, the resilience of both areas can still be further improved by enhancing the preparedness and/or by reducing the vulnerability.

As explained in the above subsections, among the preparedness dimensions, community is the one with the highest weight, and current condition shows that even though the level of activity to improve the community competence sub-dimension is considered high, the level of understanding of the community toward disaster risk and mitigation is still low. This situation implies that they may not be involved in disaster mitigation activities (such as disaster education/socialization/simulation) or they attended the activities but do not understand the content being explained. This situation can be managed by recruiting more community leaders as disaster mitigation spoke-persons so that they can explain disaster risk and mitigation in the same language that the community use, probably by quoting the local wisdom, to ensure that the message is understood by the residents.

Other aspect of preparedness that still needs to be improved is the economic dimension. This can be done by encouraging the residents to have personal savings and to always put aside a part of their income as a reserve fund for emergency purpose. Other measure that can be taken by the government is to encourage insurance companies to offer micro-insurance program for residents living in the disaster prone area with small premium, for instance, in exchange for a tax rebate. Micro-insurance can help to shorten the recovery period of households in the aftermath of a disaster.

In terms of vulnerability, the social and economic vulnerability can still be reduced. One way to do it in Cilacap is by decreasing the percentage of residents living in poverty, as there is an integral link between reduction of both poverty and natural disaster-risk [11]. Poverty reduction for instance can be done by encouraging the head of household to have more ways to earn a living and encouraging the housewives to engage themselves in home-based industry as micro- and small-businesses can alleviate poverty [38]. Concerning Padang, it can be done by decreasing the portions of expense for everyday needs, by educating the household especially the housewives to manage their income and spend it wisely. However it requires a long-term socialization, education program and cooperation between the local government, NGOs and the community leaders.

5. Conclusions and recommendations

The paper presents a framework to assess the resilience of a disaster-prone area in Indonesia towards natural disasters. The resilience index is measured as a ratio of preparedness (representing the capacity to overcome disaster) to vulnerability (representing the exposure towards disaster). The preparedness and vulnerability scores are calculated using AHP. Dimensions and sub-dimensions of preparedness and vulnerability are determined based on the results from IDIs and FGDs with representatives from government institutions, NGOs, The Indonesia Red Cross, the community leaders, and from literature review. The dimensions for preparedness are social, community capacity, economic, institution, and infrastructure, while dimensions for vulnerability are similar dimensions for preparedness plus the hazard.

The preparedness and vulnerability scores are calculated as the composite of indicators. We use 49 indicators for preparedness and 18 indicators for vulnerability. The weights of all dimensions and sub-dimensions are determined by employing pair-wise comparisons of AHP. We conducted IDIs with eight informants (representatives from government institutions and NGOs in Jakarta, Cilacap and Padang) for this purpose.

We apply the framework to assess the resilience of Cilacap and Padang towards natural disasters. We use secondary data published or supplied by BPS and BPBD Cilacap and Padang, and also the results of surveys that are conducted in both areas. Cilacap has the scores of 0.70 and 0.41 for preparedness and vulnerability, respectively, hence the score of 1.70 for resilience, indicating that currently, Cilacap regency has the capacity to overcome the vulnerability to disaster. Padang has the scores of 0.74 and 0.40 for preparedness and vulnerability, respectively, hence 1.83 in resilience index, also implying that currently, the city of Padang has the capacity to overcome the vulnerability towards disaster. The resilience can be further enhanced by increasing the preparedness and/or reducing the vulnerability. For the case of Cilacap, the community and economics dimensions of preparedness are still needed to be enhanced, and the social and economic dimensions of vulnerability are still required to be reduced. For the case of Padang, the community, economics, and institutional dimensions of preparedness are still in need for improvement while the economics dimension of vulnerability is still required to be decreased.

This research is a first step in developing the framework to assess the resilience of disaster-prone areas in Indonesia toward natural disasters. The framework still needs improvements to ensure accurate assessment. For instance, due to the difficulty in gathering the secondary data, the number of indicators of some sub-dimensions in preparedness and vulnerability is still below three that may not accurately represent the sub-dimensions. Furthermore, certain indicators that cannot be measured using secondary data are measured using survey questionnaire, and hence the accuracy of the results depend on the sample size. We will address these limitations in the future research.

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